



Research Article

The Double Burden of Malnutrition: Coexisting Undernutrition and Overweight/Obesity Among Adolescents in Tribal and Peri-Urban Dadra and Nagar Haveli — A Community-Based Comparative Study

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Abstract: Background: India's adolescents face persistent undernutrition alongside rising overweight. Tribal and fast-urbanising peri-urban communities may be at different stages of the nutrition transition, but they have rarely been compared within one district. Dadra and Nagar Haveli is a predominantly tribal, rapidly industrialising Union Territory with no published adolescent data on this double burden of malnutrition (DBM). **Objective:** To estimate and compare the prevalence of undernutrition (stunting, thinness), overweight/obesity and their coexistence among adolescents in tribal and peri-urban Dadra and Nagar Haveli, and to identify factors associated with thinness and overweight/obesity. **Methods:** Community-based comparative cross-sectional study (STROBE-compliant) conducted between July 2025 and July 2026 among 820 adolescents aged 10–19 years (tribal n = 412, peri-urban n = 408), selected by two-stage cluster sampling (30 clusters). Height, weight and waist circumference were measured with standardised methods, height-for-age (HAZ) and BMI-for-age (BAZ) z-scores were derived from the WHO 2007 growth reference. Prevalence ratios (PR) and cluster-adjusted multivariable logistic regression (adjusted odds ratios, aOR, with 95% CI) were computed. **Results:** Overall, 33.8% (30.6–37.1) of adolescents were undernourished and 9.1% (7.4–11.3) were overweight/obese. Compared with peri-urban peers, tribal adolescents had a higher prevalence of stunting (29.4% vs 17.2%, PR 1.71, 95% CI 1.32–2.22) and thinness (22.3% vs 7.1%, PR 3.14, 95% CI 2.12–4.66), and a lower prevalence of overweight/obesity (4.9% vs 13.5%, PR 0.36, 95% CI 0.22–0.59). Individual-level DBM (stunting with overweight/obesity) affected 1.2% and 3.2% respectively (p = 0.054), community-level coexistence was present in 2/15 tribal and 6/15 peri-urban clusters. Thinness was independently associated with tribal residence (aOR 1.94, 95% CI 1.15–3.28, p = 0.013), household food insecurity (aOR 1.69, 95% CI 1.08–2.66, p = 0.023) and inversely with adequate dietary diversity (aOR 0.60, 95% CI 0.40–0.89, p = 0.011). Recreational screen time >2 h/day was independently associated with overweight/obesity (aOR 1.77, 95% CI 1.13–2.76, p = 0.013). **Conclusion:** Tribal adolescents in Dadra and Nagar Haveli carry predominantly undernutrition, whereas peri-urban adolescents show an established double burden. Double-duty actions — food security and dietary diversity together with limits on screen time and processed-snack intake, delivered through school and RKSK platforms — should be tailored to each setting.

Keywords: Adolescents, Tribal Population, Undernutrition, Stunting, Thinness, Overweight and Obesity

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INTRODUCTION

The double burden of malnutrition (DBM) the coexistence of undernutrition with overweight, obesity or diet-related non-communicable diseases within the same population, household or individual is now the dominant nutrition challenge in low- and middle-income countries. Adolescence (10–19 years) is a critical window: it is the second most rapid period of growth after infancy, nutritional deficits accumulated in childhood can be partly recovered, and dietary and activity habits that persist into adulthood are formed. Global analyses show that, while thinness in children and adolescents has plateaued, the prevalence of obesity has risen steeply, and the shift has been fastest in South Asia. This shift is driven by the nutrition transition: urbanisation, sedentary employment and screen-based leisure, and replacement of traditional diets with energy-dense, processed foods [1-3].

India illustrates this transition. The Comprehensive National Nutrition Survey (CNNS, 2016–18) documented a high burden of thinness and stunting among adolescents together with an emerging burden of overweight, obesity and metabolic risk markers. Secondary analyses of CNNS have shown that more than half of Indian adolescents experience some form of the double burden when anthropometric and micronutrient indicators are combined, with socioeconomic disadvantage, caste and low dietary diversity as major correlates. National surveys, however, are powered for state-level estimates and cannot describe contrasts within small Union Territories, where tribal hamlets and industrial suburbs often lie only a few kilometres apart [4-5].

Scheduled Tribe (tribal) communities, who make up about 8.6% of India's population, have consistently worse nutritional indicators than non-tribal groups because of food insecurity, poor access to services and dependence on seasonal agriculture and wage labour. Community surveys among indigenous children in the Western Ghats and among rural adolescents in eastern India show that overweight is beginning to appear even where undernutrition remains highly prevalent. How far the transition has progressed in tribal compared with neighbouring non-tribal peri-urban adolescents in the same district has seldom been measured directly.

Dadra and Nagar Haveli (DNH) is well suited to this comparison. More than half of its population belongs to Scheduled Tribes —predominantly Warli, Kokna and Dhodia — living in forested, agrarian villages, while the area around Silvassa has become one of western India's fastest-growing industrial hubs, attracting large migrant populations. To our knowledge, no community-based study has described adolescent DBM in this Union Territory. We therefore aimed to

- Estimate and compare the prevalence of stunting, thinness, overweight/obesity and central adiposity among adolescents in tribal and peri-urban DNH
- Quantify their coexistence at individual and community levels
- Identify sociodemographic, dietary and lifestyle factors associated with thinness and with overweight/obesity. We hypothesised that tribal adolescents would have a higher prevalence of undernutrition and peri-urban adolescents a higher prevalence of overweight/obesity

MATERIALS AND METHODS

Study Design and Reporting

This was a community-based comparative cross-sectional study, reported in accordance with the STROBE statement for cross-sectional studies. The completed STROBE checklist is provided as Supplementary File 1.

Study Setting and Period

The study was conducted in the field practice areas of the Department of Community Medicine, NAMO Medical Education and Research Institute (NAMOMERI), Silvassa, in the district of Dadra and Nagar Haveli (area 491 km², Census 2011 population 343,709). Two strata were defined a priori:

- A tribal stratum, comprising revenue villages in which ≥80% of households belonged to Scheduled Tribes, served by the Rural Health Training Centre
- A peri-urban stratum, comprising census towns and wards on the industrial fringe of Silvassa, served by the Urban Health Training Centre. Data were collected from July 2025 to July 2026

Participants

Adolescents aged 10–19 years who had lived in the study area for at least 6 months were eligible. We excluded adolescents with a chronic illness known to affect growth (e.g., congenital heart disease, chronic kidney disease, tuberculosis under treatment), a physical deformity preventing accurate anthropometry, acute febrile illness on the day of the survey (rescheduled), and girls who were pregnant or within 6 months postpartum.

Sample Size

Sample size was calculated for comparing two independent proportions, with the prevalence of overweight/obesity as the primary comparison. Assuming an anticipated prevalence of 13% among peri-urban and 6% among tribal adolescents, two-sided $\alpha = 0.05$ and 80% power, 275 adolescents were required per stratum. Multiplying by a design effect of 1.5 for cluster sampling gave 412, and allowing for 5% non-response gave a target of 433 per stratum (866 in total).

Sampling

A two-stage cluster design was used in each stratum. In the first stage, 15 villages (tribal) and 15 wards (peri-urban) were selected by probability proportional to size from the updated population lists of the health training centres. In the second stage, a house-to-house listing was done in each cluster; households were selected by systematic random sampling from a random start, and all eligible adolescents in selected households were invited until approximately 30 adolescents per cluster had been enrolled. Households found locked were revisited up to three times before being recorded as non-response.

Data Collection Instruments

A pre-tested, semi-structured questionnaire was translated into Gujarati and Hindi and back-translated, with oral explanation in the Varli dialect where required. It was piloted on 30 adolescents from a non-study cluster. Trained

medical interns and community health workers, supervised by faculty, administered it face to face. The questionnaire covered sociodemographic characteristics, household food insecurity (FIES), dietary diversity (MDD-W), frequency of packaged snacks, physical activity and recreational screen time.

Anthropometry

Measurements followed standardised procedures. Height was measured to the nearest 0.1 cm with a portable stadiometer, weight to the nearest 0.1 kg on a calibrated digital scale, waist circumference to the nearest 0.1 cm. Each measurement was taken twice (third if discrepancy >0.5 cm or >0.1 kg), the mean of the two closest values was used. Height-for-age (HAZ) and BMI-for-age (BAZ) z-scores were computed with WHO AnthroPlus using the WHO 2007 growth reference.

Outcome Definitions

Stunting was defined as HAZ<-2 SD, thinness as BAZ<-2 SD (severe thinness<-3 SD), overweight as BAZ >+1 to ≤+2 SD, obesity as BAZ > +2 SD. Central adiposity was defined as waist-to-height ratio (WHtR) ≥0.5. Individual-level DBM was defined as stunting coexisting with overweight/obesity. Community-level DBM was defined as stunting ≥20% or thinness ≥10% together with overweight/obesity ≥10% in the same cluster.

Statistical Analysis

Continuous variables are presented as mean ± SD, categorical variables as n (%). Prevalences are reported with Wilson 95% CI. Crude prevalence ratios (PR) were estimated by the log method. Factors associated with thinness and overweight/obesity were examined by binary logistic regression with cluster-robust standard errors. Variables with p<0.20 in bivariable analysis, together with a priori confounders, were entered into multivariable models. A two-sided p<0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of NAMOMERI, Silvassa. Written informed consent was obtained from parents/guardians, with assent from adolescents aged 10–17 years. Adolescents found to be severely thin or obese were referred to the Adolescent Friendly Health Clinic under RKSK.

RESULTS

Participant Flow and Characteristics

Of 910 eligible adolescents enumerated (tribal 458, peri-urban 452), 820 were included in the analysis (response rate 90.0% and 90.3% respectively, Figure 1). Mean age was similar in the two strata (Table 1). Tribal adolescents were more

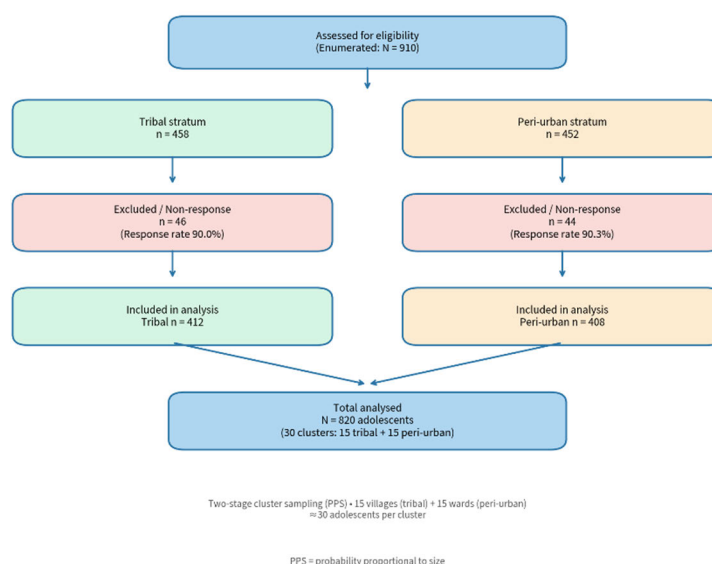


Figure 1: Flow of Participants Through the Study (STROBE)

PPS = Probability Proportional to Size. of 910 Eligible Adolescents Enumerated (Tribal 458, Peri-Urban 452), 820 Were Included (Response Rate ≈90%)

Table 1: Sociodemographic, Dietary and Lifestyle Characteristics of Adolescents, By Setting (N = 820)

Characteristic	Tribal (n = 412)	Peri-urban (n = 408)	Total (N = 820)	p-value
Age, years, Mean $\pm$ SD	14.5 $\pm$ 3.0	14.5 $\pm$ 2.8	14.5 $\pm$ 2.9	0.989
Late adolescence (15–19 y)	214 (51.9)	208 (51.0)	422 (51.5)	0.783
Female	200 (48.5)	212 (52.0)	412 (50.2)	0.328
Lower socioeconomic class (BG Prasad IV–V)	302 (73.3)	165 (40.4)	467 (57.0)	<0.001
Mother's education $\leq$ primary	272 (66.0)	124 (30.4)	396 (48.3)	<0.001
Moderate/severe household food insecurity	147 (35.7)	56 (13.7)	203 (24.8)	<0.001
Adequate dietary diversity ($\geq$ 5 of 10 groups)	144 (35.0)	248 (60.8)	392 (47.8)	<0.001
Packaged/processed snacks $\geq$ 4 days/week	101 (24.5)	210 (51.5)	311 (37.9)	<0.001
Recreational screen time >2 h/day	83 (20.1)	204 (50.0)	287 (35.0)	<0.001
Physically active $\geq$ 60 min/day	281 (68.2)	164 (40.2)	445 (54.3)	<0.001
Receives school mid-day meal	248 (60.2)	214 (52.5)	462 (56.3)	0.025

Values are n (%) unless stated otherwise. p-values from the Pearson χ^2 test (categorical variables) or Student's t-test (age). SES = socioeconomic status (modified BG Prasad scale), dietary diversity from a 24-h recall over 10 food groups (MDD-W), food insecurity by FIES (raw score 4–8)

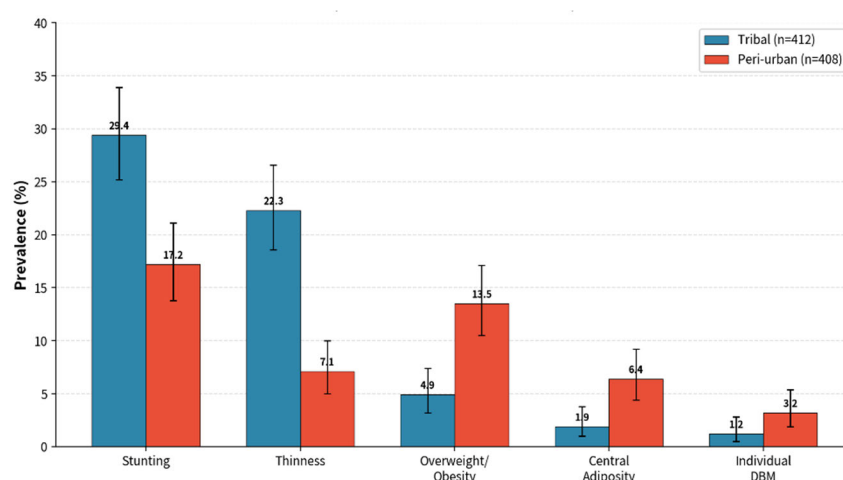


Figure 2: Comparison of Nutritional Status and Double Burden of Malnutrition Among Tribal and Peri-Urban Adolescents

likely to belong to lower socioeconomic classes (73.3% vs 40.4%), to have mothers with no more than primary education (66.0% vs 30.4%) and to live in food-insecure households (35.7% vs 13.7%, all $p < 0.001$). Peri-urban adolescents were more likely to have adequate dietary diversity, consume packaged snacks frequently, and exceed 2 h/day of recreational screen time, and less likely to be physically active every day.

Prevalence of Undernutrition and Overweight/Obesity

Across the whole sample, the prevalence (95% CI) was 23.3% (20.5–26.3) for stunting, 14.8% (12.5–17.3) for thinness, 33.8% (30.6–37.1) for any undernutrition and 9.1% (7.4–11.3) for overweight/obesity. Mean HAZ was -1.44 ± 1.04 in tribal and -0.95 ± 1.07 in peri-urban adolescents ($p < 0.001$), mean BAZ was -1.06 ± 1.23 and -0.30 ± 1.21 respectively ($p < 0.001$).

Differences between strata are shown in Table 2 and Figure 2. Tribal adolescents had a 1.7-fold higher prevalence of stunting (PR 1.71, 95% CI 1.32–2.22) and a 3.1-fold higher prevalence of thinness (PR 3.14, 95% CI 2.12–4.66). Severe thinness occurred in 6.1% of tribal versus 1.0% of peri-urban adolescents. Conversely, overweight/obesity was about one-third as common in the tribal stratum (4.9% vs 13.5%, PR 0.36, 95% CI 0.22–0.59). Nearly half of tribal adolescents (44.9%) had at least one form of undernutrition, compared with 22.5% of peri-urban adolescents.

Coexistence of Undernutrition and Overweight (Double Burden)

At the individual level, 18 adolescents (2.2%, 95% CI 1.4–3.4) were simultaneously stunted and overweight/obese: 5 (1.2%) in the tribal stratum and 13 (3.2%) in the peri-urban stratum ($p = 0.054$). At the community level, the double burden was present in 6 of 15 peri-urban wards (40.0%) compared with 2 of 15 tribal villages (13.3%).

Sex-stratified prevalences are shown in Table 3. Among tribal adolescents, stunting was more common in boys than in girls (34.9% vs 23.5%, $p = 0.011$), and overweight/obesity was more common in girls (7.0% vs 2.8%, $p = 0.049$). No sex differences were observed in the peri-urban stratum.

Table 3: Prevalence of Thinness, Stunting and Overweight/Obesity by Sex Within Each Setting

Setting	Indicator	Boys, n (%)	Girls, n (%)	p-value
Tribal	Thinness	41 (19.3)	51 (25.5)	0.133
Tribal	Stunting	74 (34.9)	47 (23.5)	0.011
Tribal	Overweight/obesity	6 (2.8)	14 (7.0)	0.049
Peri-urban	Thinness	14 (7.1)	15 (7.1)	0.979
Peri-urban	Stunting	30 (15.3)	40 (18.9)	0.340
Peri-urban	Overweight/obesity	30 (15.3)	25 (11.8)	0.299

Tribal: boys' n = 212, girls' n = 200, peri-urban: boys' n = 196, girls' n = 212. p-values from the χ^2 test.

Table 4: Factors Associated with Thinness (BAZ < -2 SD): Bivariable and Multivariable Logistic Regression (N = 820, events = 121)

Variable	cOR (95% CI)	p-value	aOR (95% CI)	p-value
Tribal setting (ref: peri-urban)	3.76 (2.33–6.06)	<0.001	1.94 (1.15–3.28)	0.013
Female (ref: male)	1.22 (0.84–1.77)	0.285	1.42 (0.96–2.11)	0.081
Age 15–19 y (ref: 10–14 y)	1.11 (0.77–1.60)	0.566	1.26 (0.83–1.90)	0.279
Lower SES, BG Prasad IV–V	2.89 (1.71–4.86)	<0.001	1.51 (0.78–2.91)	0.224
Mother's education $\leq$ primary	2.27 (1.45–3.54)	<0.001	1.23 (0.78–1.95)	0.374
Moderate/severe food insecurity	2.51 (1.69–3.73)	<0.001	1.69 (1.08–2.66)	0.023
Adequate dietary diversity	0.41 (0.28–0.60)	<0.001	0.60 (0.40–0.89)	0.011
Packaged snacks $\geq$ 4 days/week	0.54 (0.37–0.80)	0.002	0.81 (0.55–1.21)	0.310
Screen time > 2 h/day	0.46 (0.31–0.67)	<0.001	0.66 (0.43–1.01)	0.056
Physically active $\geq$ 60 min/day	1.79 (1.22–2.61)	0.003	1.35 (0.94–1.92)	0.100

cOR = crude odds ratio, aOR = adjusted odds ratio (adjusted for all variables in the table). Standard errors adjusted for clustering at village/ward level (30 clusters). Hosmer–Lemeshow χ^2 = 2.35, p = 0.97, AUC = 0.73, maximum VIF = 1.51.

Table 5: Factors Associated with Overweight/Obesity (BAZ > +1 SD): Bivariable and Multivariable Logistic Regression (N = 820, Events = 75)

Variable	cOR (95% CI)	p-value	aOR (95% CI)	p-value
Tribal setting (ref: peri-urban)	0.33 (0.21–0.50)	<0.001	0.70 (0.43–1.16)	0.168
Female (ref: male)	1.08 (0.58–2.01)	0.807	1.01 (0.53–1.91)	0.974
Age 15–19 y (ref: 10–14 y)	1.15 (0.69–1.93)	0.592	1.04 (0.61–1.78)	0.884
Lower SES, BG Prasad IV–V	0.39 (0.22–0.70)	0.002	0.65 (0.34–1.23)	0.181
Mother's education $\leq$ primary	0.54 (0.34–0.86)	0.009	0.92 (0.56–1.51)	0.727
Moderate/severe food insecurity	0.50 (0.25–1.00)	0.049	0.88 (0.44–1.76)	0.720
Adequate dietary diversity	2.36 (1.43–3.88)	<0.001	1.66 (0.97–2.84)	0.064
Packaged snacks $\geq$ 4 days/week	2.39 (1.35–4.23)	0.003	1.72 (0.96–3.09)	0.068
Screen time > 2 h/day	2.30 (1.53–3.48)	<0.001	1.77 (1.13–2.76)	0.013
Physically active $\geq$ 60 min/day	0.44 (0.27–0.73)	0.001	0.59 (0.33–1.04)	0.068

Abbreviations as in Table 4. Hosmer–Lemeshow χ^2 = 6.93, p = 0.54, AUC = 0.72

Factors Associated with Thinness

In the multivariable model (Table 4, 121 events), tribal residence remained independently associated with thinness (aOR 1.94, 95% CI 1.15–3.28, p = 0.013). Moderate/severe household food insecurity was associated with higher odds of thinness (aOR 1.69, 95% CI 1.08–2.66, p = 0.023) and adequate dietary diversity with lower odds (aOR 0.60, 95% CI 0.40–0.89, p = 0.011). The model was well calibrated (Hosmer–Lemeshow χ^2 = 2.35, p = 0.97) and had acceptable discrimination (AUC 0.73).

Factors Associated with Overweight/Obesity

For overweight/obesity (Table 5, 75 events), recreational screen time > 2 h/day was the only independent correlate (aOR 1.77, 95% CI 1.13–2.76, p = 0.013). The strong crude inverse association with tribal residence was substantially attenuated after adjustment (aOR 0.70, 95% CI 0.43–1.16, p = 0.168). Frequent packaged-snack consumption and daily physical activity showed associations in the expected directions that did not reach statistical significance.

DISCUSSION

Principal Findings

This community-based comparison is, to our knowledge, the first to describe the double burden of malnutrition among adolescents in Dadra and Nagar Haveli. Three findings stand out. First, undernutrition dominates in tribal villages: almost half of tribal adolescents were stunted and/or thin, and thinness was three times as common as among their peri-urban peers. Second, the peri-urban fringe of Silvassa already shows an established double burden: one in seven adolescents (13.5%) was overweight/obese, while about one in five remained stunted or thin, and 6 of 15 peri-urban wards met our community-level DBM definition. Third, the correlates differed by outcome food insecurity and poor dietary diversity for thinness, and sedentary screen time for overweight/obesity — which argues against a single 'nutrition' intervention for both settings.

Comparison with Pther Studies

Our findings are consistent in direction with national evidence from CNNS and secondary analyses showing high thinness and stunting among Indian adolescents, higher in Scheduled Tribe and poorer households, alongside a smaller but growing prevalence of overweight and obesity. The pattern in tribal villages — high undernutrition with a small but non-zero prevalence of overweight — resembles that reported among indigenous children of the Western Ghats and rural adolescents in West Bengal.

Possible Mechanisms

The attenuation of the tribal–thinness association after adjustment for food insecurity and dietary diversity indicates that much of the excess undernutrition among tribal adolescents reflects modifiable deprivation rather than ethnicity itself. In peri-urban areas, industrial employment, cash incomes, easy availability of low-cost packaged foods and the spread of smartphones create an obesogenic environment. The stunted-overweight phenotype is consistent with the developmental hypothesis that early-life growth restriction followed by later exposure to energy-dense diets predisposes to central fat deposition and later cardiometabolic risk.

Public-Health Implications

The results support ‘double-duty’ actions that address undernutrition and overweight together. In tribal villages, priorities include strengthening household food security, extending supplementary nutrition to older adolescents, and nutrition counselling that promotes dietary diversity from locally available foods. In peri-urban wards, school- and RKSK-based programmes should add screen-time guidance, safe spaces for physical activity and regulation of the marketing and sale of processed foods near schools.

Strengths and Limitations

Strengths include the community (rather than school) base, direct comparison of two contrasting settings within one district using identical methods, standardised anthropometry, and cluster-adjusted analysis. Limitations include the cross-sectional design, self-reported diet and activity data, lack of pubertal staging, absence of micronutrient or metabolic markers, and relatively few overweight/obesity events for the number of covariates.

CONCLUSION

Adolescents in Dadra and Nagar Haveli face a setting-specific double burden of malnutrition. In tribal villages undernutrition clearly predominates and overweight is still uncommon, while in the peri-urban industrial fringe overweight/obesity now accompanies persistent undernutrition. Household food insecurity and poor dietary diversity drive thinness, and sedentary screen time is the main modifiable correlate of overweight. Programmes should therefore combine food-security and dietary-diversity measures with activity- and screen-time interventions, weighted by setting.

Declarations

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Author Contributions

Dr Mitali P.: conceptualisation, methodology, supervision, writing – original draft. Dr Darshan M.: investigation, data curation, formal analysis, writing – review and editing. All authors approved the final manuscript.

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None

Conflicts of interest

The authors declare no conflicts of interest.

Ethics Approval

Institutional Ethics Committee, NAMOMERI, Silvassa.

Data Availability

De-identified data are available from the corresponding author on reasonable request.

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